A Summary of the Bank of Canada Conference on Fixed-Income Markets, 3–4 May 2006

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The Bank of Canada has hosted an annual economic conference since 1990 to present its own research and to promote discussion with leading external researchers on topics of mutual interest and direct policy relevance. The 2006 conference focused on various aspects of fixed-income markets both in Canada and around the world. This topic is important to the Bank for a number of reasons that will be discussed briefly below. The papers and discussions covered such topics as the efficiency of fixed-income markets, price formation, the determinants of the yield curve, and volatility modelling.[1] Other aspects of fixed-income markets will be the focus of ongoing research at the Bank and of future workshops and conferences.

The Bank of Canada's interest in fixed-income markets spans a number of its functional areas of responsibility, which include monetary policy, funds management, and financial system stability and efficiency. Monetary policy concerns the setting of a target for the overnight rate to affect an array of longer-maturity interest rates to achieve a 2 per cent inflation target. The relationship between the yields on short- and long-maturity bonds is known as the yield curve and is the subject of much study. For example, historically, the yield curve seems to have been a good predictor of future real activity and inflation. Thus, a better understanding of yield-curve dynamics could be helpful in contributing to the monetary policy decision-making process. This would involve improving our knowledge of the impact of the policy rate on the total shape of the yield curve.

Funds-management policy covers the Bank of Canada's role as the fiscal agent for the Government of Canada. The Bank manages the cash reserves of the government, issues and manages the domestic-currency debt, and provides policy advice on these and related subjects. In this regard, the Bank has a keen interest in the determinants of liquidity in bond markets and their valuation. In addition, the Bank manages the foreign exchange reserves of the government through a currency- and maturity-matched asset-liability framework that raises money at AAA Government of Canada rates and invests in AAA and somewhat lower-rated fixed-income instruments around the world. An improved understanding of international yield-curve dynamics would allow the Bank to better optimize the structure of the assets and liabilities in the fund, given the constraints under which it operates.

Finally, part of the Bank's mandate is to promote the safety, soundness, and efficiency of the financial system, both in Canada and internationally. Fixed-income markets constitute an integral part of the financial system, and their efficiency and stability are crucial for economic growth and development. The Bank needs to understand better whether Canadian fixed-income markets are stable and are functioning as efficiently as they can by international standards.

The 2006 conference brought together top academics and central bankers from around the world to discuss leading-edge work in the field of fixed-income research.

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1. Conference papers and discussions are available on the Bank of Canada's website (www.bankofcanada.ca/en/conference/2006/econ_conf2006.html).

Below is a short summary of each paper and the ensuing discussion. The conference culminated in a panel discussion involving a representative of the Bank of Canada, a representative from the international markets, and a representative of the Canadian financial sector, each giving their unique perspective on the presented research and the field in general.

Session 1: Prices and Liquidity

Liquidity is a fundamental aspect of financial markets. Liquid markets allow participants to trade even large quantities quickly and with little or no impact on prices.[2] The degree of liquidity and its determinants are important factors for the overall level of financial efficiency and stability of a market and are thus of key concern for policy-makers.[3] The two papers in this session examine how certain market characteristics affect liquidity in the market and in the price-determination process.[4]

Amy Edwards (U.S. Securities Exchange Commission), **Mahendrarajah Nimalendran** (University of Florida and U.S. Securities Exchange Commission), and **Michael Piwowar** (U.S. Securities Exchange Commission) examine the reduction in transactions costs observed in the U.S. corporate bond market following the increase in price transparency associated with the new Trade Reporting and Compliance Engine (TRACE). The TRACE system was designed to report and disseminate transactions information on corporate bonds not traded on any exchange. This new system began reporting transactions prices on a subset of bonds in July 2002 and on all TRACE-eligible bonds in October 2004.

The authors investigate which of three competing hypotheses is most likely responsible for the reduction in transactions costs. The first hypothesis suggests that enhanced transparency leads to increased competition among dealers. Investors can observe the prices that others are paying and receiving, and demand the same or better. The second hypothesis suggests that transparency leads to an improvement in the informational efficiency of the market. Trade-based information made available to the greater market limits the ability of informed traders to exploit their private information. Lastly, some researchers have argued that transparency in trades allows investors to determine the relative liquidity of bonds. Since investors prefer higher levels of liquidity, all else being equal, increased transparency may lead to the concentration of liquidity in a set of securities.

The paper by Edwards, Nimalendran, and Piwowar rejects all three of the hypotheses to explain the effect of transparency on transactions costs. They find that price competition among corporate bond dealers increased because of transparency but it did not influence transactions costs. Regarding the second hypothesis, transactions costs are found to be positively related to the probability of trading with an informed investor (the inverse of a measure of informational efficiency). However, the change in transparency had no effect on the degree of informational efficiency. Finally, evidence is found that transactions costs are negatively related to measures of liquidity concentration, but that liquidity concentration in the bond market was unaffected by the transparency changes. As such, the question is still open regarding the mechanism through which transparency enhancements can lower transactions costs in the corporate bond market.

In his discussion, **David Goldreich** (University of Toronto) emphasized the importance of the question being addressed: why exactly does increased price transparency lower transactions costs? While the three leading hypotheses were all rejected by the data, he argued that this is still preliminary work and that further examination of the question and of each hypothesis is still required. Goldreich made the point that the measures used in the paper for competition, liquidity concentration, and informational efficiency are all proxies and that alternative indicators should be investigated.

Christopher D'Souza (Bank of Canada), **Ingrid Lo** (Bank of Canada), and **Stephen Sapp** (University of Western Ontario) emphasize that it is important to account for the structure and organization of a financial market when investigating how prices and the provision of liquidity evolve over time. In Europe, market-makers using the MTS[5] electronic platform for interdealer trading of government securities must continuously

2. An alternative definition of a liquid market is that the price reverts quickly to the initial level after a trade.

3. See Bauer (2004) for an overview of the concept of efficiency.

4. See Zorn (2004) for a summary of a previous Bank of Canada workshop on these topics.

5. MTS—Mercato Telematico dei Titoli di Stato—is the dominant electronic platform for interdealer trading of government securities in Europe. Government bonds are traded on two platforms: EuroMTS and MTS domestic markets. The former is the electronic market for euro benchmark bonds, while the latter lists the whole yield curve of individual countries. Both platforms are electronic limit-order books in which dealers place limit and market orders. Dealers can see orders with the five best prices on both sides of the market.

post buy and sell limit-orders within a maximum bid-ask spread, for a minimum quote amount, for a given period of time each day. These provisions are collectively known as the "liquidity pact." In Canada, a large proportion of government securities trading takes place via interdealer brokers. While there are no formal quoting obligations placed on the dealers in Canada, they commit themselves to trade continuously in the market by posting a bid and an ask price for each government security.

The authors find that, for short-term government securities, the price and liquidity dynamics for Canadian securities are similar to those of European securities despite the large differences in institutional structure. This, in turn, suggests that a liquidity pact in Canada may not improve market quality. Using a vector-autoregression model with prices, order flow, order imbalances, and bid-ask spreads, the authors find that order flow has a permanent and positive impact on price, while spreads are informative and have a long-run impact on prices only in Canada. The fact that spreads do not convey information in the European market is attributed to the differences in market structure, particularly the presence of the liquidity pact in MTS. Both markets are found to be relatively efficient, but there is some evidence that the European market is slightly more efficient in that it does reflect fundamental information in a shorter amount of time.

In his comments, **Joshua Slive** (HEC Montréal) identified two different questions addressed in the paper: (i) do signed order flow and/or order imbalance explain movements in prices; and, (ii) what are the linkages between liquidity and price formation? Slive suggested that a structural estimation approach would be preferable to a vector autoregression if the first question were the focus of the paper, since the demand and supply of liquidity cannot be considered to be independent. Slive argued that the paper should instead focus directly on the linkages between liquidity and price discovery, and on whether the speed of price formation varies with market liquidity. The discussant also recommended that the authors develop a theoretical model to motivate the empirics of the paper.

Session 2: Links between Cash and Derivatives Markets

Fixed-income instruments trade in both cash (or spot) and derivatives markets. The growth of derivatives markets in recent years has proceeded faster than the research done to understand their characteristics and functioning. With their increasingly important role, policy-makers are looking to improve their understanding of how these markets operate and how they are linked with other financial markets and the real economy.

Bryan Campbell (CIRANO, Concordia University) and **Scott Hendry** (Bank of Canada) examine the price-discovery process for the 10-year government bond markets in both Canada and the United States. Their work compares the contribution to price discovery of both the futures market and the underlying spot market for the 10-year government bond in each country. In general, the futures market dominates the price-discovery process with approximately 70 per cent of price discovery occurring in both the Canadian and the U.S. futures markets. These results are remarkably similar across the two countries despite the large differences in the sizes of their markets. Daily changes in the price-discovery process are found to be related, in part, to bid-ask spreads and trading volumes, but much remains unexplained.

In his discussion, **Bruce Mizrach** (Rutgers University) emphasized that one must be wary of these price-discovery information shares because they are based on reduced-form models that include unobserved components. While such models represent a useful summary statistic of the relative importance of different markets, he recommended that future work should concentrate instead on the direct estimation of the underlying structural model to try to get a clearer picture of the actual price-discovery process.

Prachi Deuskar (New York University), **Anurag Gupta** (Case Western Reserve University), and **Marti Subrahmanyam** (New York University) examine the effect of liquidity on interest rate options. Their paper identifies a systematic common factor that drives liquidity, across both option maturities and strike rates. They find that, contrary to results for most other markets, liquidity has a negative effect on option prices—illiquid options trade at higher prices relative to liquid options after controlling for other variables. The common liquidity factor is itself driven by the changes in uncertainty in the equity and fixed-income markets. An increase in uncertainty in the equity and bond markets appears to cause a negative liquidity shock in the interest rate options market as traders attempt to manage their risk. It is not the expectations about inflation or growth that seem to affect the liquidity in interest rate options—it is the uncertainty about

these expectations that affects the liquidity in this market. There is still, however, a large amount of variation in option-market liquidity that is yet to be explained. Further work should examine how the liquidity of this market behaves during crisis events and how liquidity effects co-move across the underlying asset market and the derivatives market.

Haitao Li (University of Michigan), in his comments, wondered whether the results would be different if exchange-traded interest rate options, for which a much richer set of microstructure information is available, were used instead of over-the-counter (OTC) market prices. He also made the point that it would be good to consider other options markets so that measures of liquidity other than just the bid-ask spread could be examined. Also, given that the bid-ask spread is the only measure of liquidity available, a better understanding of how spreads are set by the market-makers would be very important, especially for understanding what drives the common liquidity factor.

John Kuszczak Memorial Lecture

Kenneth Singleton (Stanford University and NBER) delivered the 2006 John Kuszczak Memorial Lecture,[6] "Discrete-Time Dynamic Term Structure Models with Generalized Market Prices of Risk." This joint work with **Qiang Dai** (University of North Carolina) and **Anh Le** (New York University) develops a rich class of discrete-time, non-linear dynamic term-structure models (DTSMs) for which closed-form solutions can be found for zero-coupon bond yields and their conditional densities. This modelling framework allows much more freedom in specifying the dependence of the market price of risk on the vector of state variables. In turn, this permits the empirical investigation of much richer specifications of risk premiums than have previously been considered. Much of the current literature in this field, for example, rules out the possibility of time-varying second moments (i.e., risk) in macroeconomic models. However, the DTSMs developed in this paper allow for time-varying second moments as well as for very flexible forms of non-linearity in the conditional means of the state variables. Another advantage of this framework is that, instead of having to use approximation techniques, the models can be estimated directly, since the exact likelihood functions are known. In a highly non-linear empirical model, the authors show that, in comparison to existing linear models, they can significantly improve the model's statistical fit as well as its out-of-sample forecasting performance.

Session 3: High-Frequency Analysis of the Yield Curve

Much of the existing literature on the yield curve has been completed using lower-frequency (e.g., monthly) data. This can make it difficult to identify precisely fundamental relationships and the effects of specific shocks that occur during the month. The papers in this session use high-frequency, intraday data to examine the dynamics of the yield curve in response to order flow as well as the release of information to the marketplace.[7] These papers contribute to our understanding of the level of informational efficiency in the market (i.e., the ability and speed at which the market processes new information and moves prices to their new equilibrium values).

Paolo Pasquariello (University of Michigan) and **Clara Vega** (University of Rochester and Board of Governors of the Federal Reserve System) consider how order flow in government bond markets moves daily bond yields. The paper incorporates two realistic market frictions—information heterogeneity and imperfect competition among informed traders—and a public information signal into a trading model to study the role played by private and public information in the price-formation process in the 2-, 5-, and 10-year U.S. Treasury bond market. Consistent with the implications of the model, they find that a high dispersion of beliefs across informed traders is associated with less-aggressive trading. In addition, unanticipated order flow accounts for a larger portion of bond-yield changes when the dispersion of beliefs among market participants is high, during non-announcement days, and when the public-signal noise is high. Finally, it is found that bond-yield changes and order flow are most sensitive to Nonfarm Payroll Employment announcements.

Kathy Yuan (University of Michigan) commented on this paper by pointing out that there were certain implications of the theoretical model that were not explored in the data. For instance, the correlation of agents' information endowments could be positive

6. This annual lecture was inaugurated in 2003 in memory of John Kuszczak, a Bank of Canada researcher who died in 2002.

7. News releases are public information; in contrast, order flow can contain private information that is not available to all market participants.

or negative, with differing effects on prices, but the empirical tests only consider the positive case. It could therefore be important empirically to differentiate between positive and negative news days. There could also be an asymmetric order-flow impact following good and bad news because of short-sale and borrowing constraints. She also pointed out that order flow from one bond maturity (e.g., 5 years) could also affect yield changes in other maturities (e.g., 2 and 10 years) in addition to its own.

Michael Fleming (Federal Reserve Bank of New York) and **Monika Piazzesi** (University of Chicago, NBER, CEPR) assess the effects of Federal Open Market Committee (FOMC) announcements on the term structure of U.S. Treasury securities using high-frequency, intraday data instead of the lower-frequency data (e.g., daily, weekly, monthly) typically used in the literature. The analysis shows that the yields are quite volatile around FOMC announcements, even though the average effects of surprises in the target for the federal funds rate are fairly modest. Yield changes seem to depend not only on the surprises themselves but also on the shape of the yield curve at the time of the announcement, representing market participants' time-varying concerns about inflation. For example, a positive FOMC surprise while the yield curve is particularly steep, possibly after a period of expansionary monetary policy, may actually lower longer-term yields through a reduction in inflation expectations. The authors also find that the reaction to FOMC announcements is sluggish, largely as a result of previous rate changes that occurred outside of regularly scheduled meetings. This implies that profitable trading opportunities exist, but it is shown that trading costs largely eliminate any potential profits. Finally, the behaviour of market liquidity around FOMC announcements is quite similar to that found for other macroeconomic news announcements in that liquidity is withdrawn from the market before the announcement. However, announcements that come out slightly later than expected are associated with both longer episodes of illiquidity and greater illiquidity before the announcement. Uncertainty over the announcement time may be decreasing market liquidity around announcements.

In his discussion, **Eric Swanson** (Federal Reserve Bank of San Francisco) urged the authors to consider the effects of the content of FOMC announcements instead of just the timing. He made the point that the FOMC rate decision is no longer the true surprise variable. Instead, most new information is contained in any communication regarding the future path of policy rates. The discussant also made the point that different sources of information on the timing of FOMC announcements can yield quite different results, so each alternative should be investigated.

Session 4: No-Arbitrage Pricing and Strategies

An arbitrage trade is one where an investor can buy low and sell high to obtain an instantaneous, risk-free profit. Since there are no "free lunches" in well-functioning, competitive markets, the condition that rules out arbitrage trades puts limits on the levels of prices of different assets at a point in time. In the academic literature on the term structure, it has been shown that imposing this "no-arbitrage pricing" on the models of the yield curve has improved their forecasting abilities (Ang and Piazzesi 2003). The papers in this session use the no-arbitrage framework for other purposes.

The paper by **Ruslan Bikbov** (Columbia Business School) and **Mikhail Chernov** (Columbia Business School) re-examines the relationship between monetary and fiscal policies and the yield curve. It is now recognized that the cross-section of bond prices contains three "statistical" factors: level, slope, and curvature. In this paper, the authors use a no-arbitrage framework to include macroeconomic variables along with the statistical ones. They use an econometric approach that maximizes the ability of the macroeconomic factors to explain the yield curve. They show that the macroeconomic variables and their lags can explain 80 per cent of the variation in the short rate (level), 50 per cent of the slope of the yield curve, and 68 per cent of the 10-year term premium. In addition, the unanticipated shocks to the statistical factors are strongly correlated with three factors: the AAA credit spread, which measures a "liquidity effect"; a measure of the money supply; and the growth of the government public debt (a "fiscal policy" shock). This indicates that the yield curve contains information about a wide variety of macroeconomic factors and that the simple models of the term structure currently in use will have to be augmented to contain these factors.

Michael Gallmeyer (Texas A&M University) discussed how this approach could help to explain how monetary policy affects the economy. In current macroeconomic models, a Taylor rule that relates the short-term interest rate to the state of the economy is used to explain the behaviour of the central bank. Gallmeyer noted that

other, longer-term interest rates would also contain useful information about central bank policies. The results of the Bikbov and Chernov paper reinforce this view. Gallmeyer suggested that the authors consider looking at business cycle regimes where recessions have a significant influence on the relationship between monetary policy and output.

The paper by **Jefferson Duarte** (University of Washington), **Francis Longstaff** (UCLA), and **Fan Yu** (UC Irvine) examines the risk-return trade-off for a number of fixed-income "arbitrage" strategies. These are not, as the authors clearly note, actually arbitrage opportunities, but rather, market vernacular for fixed-income trading strategies, some of which are relatively complex. All of the strategies, irrespective of their complexity, are based on the idea of exploiting deviations of market prices from theoretical model-based prices. The authors apply their approach to the swap, Treasury, mortgage, corporate bond, and fixed-income derivatives markets. They note that some commentators have viewed the payoffs on these strategies as "picking up nickels in front of a steam-roller": investors can make many small profits but every so often are crushed by the market and earn large negative returns. The authors find, however, that some of these strategies can earn large and significant risk-adjusted returns.

David Bolder of the Bank of Canada provided the discussion. He noted that the paper had some implications for the Bank's financial system function. If many fixed-income investors are hit by the steamroller at the same time (i.e., many investors earn large negative returns), this could lead to instability as they trade to get out of the positions. Thus, central bankers should use this analysis to determine the degree of correlation among the positions in the various markets.

Session 5: Multi-Country Models of the Term Structure

Canada is often viewed as the typical "small, open economy." As a result, the Bank of Canada has an interest in how best to implement monetary policy in a country where the yield curve is subject to international influences. In most industrialized countries, the central bank is able to move the short end of the yield curve. What matters for aggregate demand, however, are long-term yields and, in an open economy, exchange rates. A multi-country model of the yield curve helps to explain how the movements at the short end translate into changes in longer-term yields and the exchange rate.

The paper by **Antonio Diez de los Rios** (Bank of Canada) proposes an essentially affine model of the joint behaviour of interest rates and the exchange rate in two countries. In the model, movements in these variables are related in such a way as to preclude the existence of arbitrage opportunities. The term structures and the expected rate of depreciation of the exchange rate are functions of both the domestic and foreign short-term interest rates. The author finds that imposing the no-arbitrage restrictions in the estimation of the model produces exchange rate forecasts that are superior to those produced by time-series methods such as a random-walk model or a vector autoregression. This is a notable result, given that the random-walk model has proved very difficult to beat in forecasting exchange rates.

In his discussion, **Adrien Verdelhan** (Boston University) viewed the model's ability to combine both term-structure and exchange rate data to yield better forecasts as promising. He suggested that the author examine further the causes of the superior forecasting ability. In particular, including terms that would help to explain the volatility of the currency would also help the model.

Fousseni Chabi-Yo (Bank of Canada) and **Jun Yang** (Bank of Canada) study the joint dynamics of bond yields and macroeconomic variables in a New Keynesian, small, open economy. This approach allows the authors to examine the impact of domestic and foreign shocks on the yield curve. Using Canadian and U.S. data, the authors find that U.S. macroeconomic shocks contribute to a larger proportion of the variation of the Canadian yield curve and the yield premium than do Canadian macroeconomic shocks. It is also shown that Canadian monetary policy and U.S. aggregate demand shocks explain most of the variations of the expected excess holding-period returns of short- and medium-term bonds. In contrast, the expected excess holding-period returns of long-term bonds are mainly driven by U.S. aggregate supply shocks.

In his discussion, **Sen Dong** (Columbia University) acknowledged the importance of explaining bond risk premiums in a model with microeconomic foundations. He emphasized, however, that the inflation-risk premium should be taken into account in the aggregate-demand dynamics. He also pointed out that the pricing mechanism used in the paper has to be consistent with the consumer's utility-maximizing problem. In addition, he suggested a richer specification for the

exchange rate dynamics and a more efficient estimation technique.

Session 6: Volatility and the Term Structure

Most of the recent term-structure literature has focused on the determinants of the levels of rates along the yield curve. However, central bankers also have a keen interest in the volatility of interest rates. The Bank of Canada, for example, has a policy role in ensuring a stable and efficient financial system. To understand stability and efficiency, the Bank needs a good understanding of the drivers of volatility.

Jefferson Duarte (University of Washington) attempts to determine if hedging activity related to the mortgage-backed-security (MBS) market has any impact on volatility in interest rate markets (i.e., treasury, swap, and associated derivatives). MBSs are difficult to price, since they contain an option that is generally exercised in the event of falling interest rates: when interest rates fall, U.S. homeowners may refinance ("prepay") their mortgages (without paying a penalty), leading to large cash inflows to MBS holders. These investors attempt to control this prepayment risk through the purchase and sale of swaps, treasuries, and related interest rate securities. The way in which this risk is hedged may lead to an increase in the volatility of U.S. Treasury bonds, or their derivatives, or both. Duarte provides a theoretical and empirical analysis of the links between prepayment risk and volatility in fixed-income markets. He finds that including prepayment information in the model improves interest rate forecasts, suggesting that MBS-hedging activity does, in fact, lead to increases in actual interest rate volatility.

In his discussion, **Daniel Smith** (Simon Fraser University) noted that, even after this very thorough analysis, a number of unanswered questions remain in this area. In particular, the relationship between volatility in U.S. Treasury bonds and the volatility of their derivatives is still not completely understood. For instance, the model used to estimate volatility in the Treasury bond market could be expanded to include regime-specific volatility factors.

In the second paper in this session, **Caio Almeida** (Ibmec Business School), **Jeremy J. Graveline** (Stanford University), and **Scott Joslin** (Stanford University) note that, in the existing literature, estimates of the term-structure models are made mainly with yield data. Interest rate options may contain information about this risk premium because their prices are sensitive to the volatility and market prices of the risk factors that drive interest rates. They include the prices of interest rate options when estimating three-factor affine term-structure models and then compare the performance of the estimated models with and without the options. The paper shows that models with options predict excess long-term rates better than those without, in both in- and out-of-sample tests. Thus, it needs to be recognized that prices of options and other derivative instruments that are sensitive to volatility will contain additional information about the future of the economy.

Christopher Jones (University of Southern California) noted that, by including interest rate options, the model in the paper improves both the ability to explain bond market volatility and the ability to forecast yield levels. This is so because existing models are created to explain the cross-section of bond prices at a given point in time, while an understanding of volatility requires an analysis of bond prices across time. By including the interest rate derivatives, the model is able to capture the time series of the data much better.

Session 7: "Might as Well Jump!"

Recently, there has been a renewed interest in examining the effects of news on financial-asset prices. In this literature, researchers have shown that news about macroeconomic variables is generally swiftly processed by financial market investors, leading to a jump, or discontinuity, in the path of the asset's price. It remains an open question, however, as to how to include jumps in formal DTSMs.

The paper by **George J. Jiang** (University of Arizona) and **Shu Yan** (University of Arizona) examines some fundamental questions in term-structure modelling. First, they examine the causes of jumps in interest rates. Second, they examine what causes the speed of these news events to vary over time. To accomplish these aims, they develop a model of the term structure of interest rates that includes jumps. The paper shows that jumps are related to movements in the short-run interest rate and macroeconomic shocks. This will be helpful in analyzing the effects of monetary policy shocks on the bond market.

Peter Christoffersen (McGill University) detailed a number of technical suggestions for the model. These mostly deal with the tricky issue of modelling bond-market volatility while including jumps. In addition,

the estimation of the models remains challenging. He suggested comparing the results of this more advanced model with some of the simpler benchmarks that have been developed in the literature. This would allow the reader to assess the value added of this paper more directly.

The main point of the paper by **Torben G. Andersen** (Northwestern University and NBER) and **Luca Benzoni** (University of Minnesota) is that the existing literature reflects a poor understanding of volatility in fixed-income markets. In particular, the standard affine term-structure model does not capture the volatility dynamics that are evident in the data. The estimated volatility variable from these models is not nearly as persistent as the volatility measured using the time series of bond prices. Thus, interest rate volatility cannot be extracted from the cross-section of bond yields in the U.S. Treasury market. This implies that hedging the risk of interest rate volatility by trading a portfolio of bonds will yield a very poor hedge, suggesting that investors need to use other instruments to manage the risk inherent in their portfolios.

Michael Johannes (Northwestern University) noted that there are three ways to model fixed-income volatility: the volatility that arises from the term-structure model; the volatility inherent in option prices; and the volatility that can be obtained from time-series data. The problem is that the three ways of measuring volatility may yield very different results. He suggested that Andersen and Benzoni's model may need to be adapted to account for jumps. If volatility does contain a systematic jump component, this may greatly complicate the hedging problem for investors.

Panel Discussions: Alternative Perspectives on Fixed-Income Markets

David Longworth (Bank of Canada) focused on the challenges in fixed-income research, on the policy implications of the conference papers for the Bank of Canada's functions, and on some areas for future research. The main challenge for researchers and policy-makers is to incorporate variables that are omitted from the models commonly used in the fixed-income literature, including domestic macroeconomic variables, foreign prices and macroeconomic variables, variables from other markets, and volatility, or jumps. The papers in the conference each made a contribution towards incorporating some of this missing information. Other challenges facing researchers include properly modelling the stability of relationships, making comparisons across markets and countries, and conducting welfare analysis via general-equilibrium models.

Longworth then outlined how the conference papers contributed to the Bank's understanding of three of its main functions: financial system stability and efficiency, monetary policy, and funds-management policy. The papers on liquidity and the price-formation process improve our understanding of the efficiency and stability of financial markets in Canada and internationally. Several papers offered insights on the extraction of information from interest rates based on current and future economic fundamentals that could be useful in the formation of monetary policy. Other papers emphasized that the communications strategy and the manner in which monetary policy announcements are made are important for the transmission of monetary policy. Finally, several of the papers offered interesting insights on various aspects of the Bank's debt-management responsibilities for the federal government. Detailed models of the level and volatility of the yield curve are necessary for building a debt-management policy to reduce funding costs for the government.

Longworth concluded that fixed-income research seems to be beginning to deal with some of the challenges that have existed for some time with respect to omitted variables, but that much more remains to be done, especially with respect to examining the stability of the estimated relationships.

Mark Caplan (BMO Nesbitt Burns) spoke from a market practitioner's perspective about the ways in which economic and market research have been used in their global trading businesses and about the types of research that should receive greater focus. He emphasized that financial markets-based research underlies everything they do as providers of financial market services. At a very basic level, research has provided the information necessary for the growth of an efficient, liquid, and well-understood capital marketplace. This information allows participants to transact confidently in fixed-income markets. Predictive models also have an important role, for both clients and BMO's own proprietary trading desks, in predicting future prices. Quantitative research is also important for model-based valuation of a wide range of new products, especially as the complexity of the market grows. Most new product advances—structured notes, hybrid derivatives, credit derivatives, inflation-linked securities—have been possible only because of

research around option pricing and measurement of volatility or correlation. Finally, the risk-management arm of financial services firms are big users of modern modelling and valuation techniques to manage their risk and the associated regulatory capital.

In looking to future research, Caplan made the point that the fixed-income market has recently experienced—and will continue to do so—considerable change, and that these developments are all worthy of further study. The first change is a splitting of the market such that practitioners now perceive it as two distinct markets: one for rates and another for credit. Owing to the growth in liquidity, transparency, and product development in the credit derivatives markets, participants are now able to manage their credit-risk exposure separately from their view of the future path of administered rates, the shape of the yield curve, and underlying macroeconomic forces. There have also been changes to the underlying functioning of the market (in both liquidity and efficiency) that provide opportunities for interesting research. The growth of China and increased globalization are two important factors affecting capital flows. Similarly, advances in electronic trading and the growth of hedge funds are two factors that have had a big effect on market structure. Finally, Caplan made a call for more research on Canada specifically.

Pierre Collin-Dufresne (Goldman Sachs Asset Management, University of California Berkeley, and NBER) provided a survey of the dynamic term-structure literature. Using a DTSM in the real world requires that a number of steps be completed. The user must write down a rather complex multi-factor model with many parameters. He or she must then derive analytic solutions for the prices of bonds or derivatives securities as well as specifying a risk-premium function. The user must then use complex empirical techniques to estimate the model and determine its predicted values for bond prices.

Despite all this structure (or perhaps as a result of all this structure), the models have not fit the data along many dimensions. As a result, researchers have turned to other sources of data for help. As shown above, using information from the derivatives markets helps to model volatility better. Using macroeconomic data to put more structure on the factors helps interpret the results. Using high-frequency data can aid in the interpretation of shocks.

Collin-Dufresne noted that DTSMs have the potential to be useful in several real-world applications. The first is to help investors in fixed-income markets. The problem with these models, however, is that the parameters and the state variables appear to change over time. This would lead to unstable portfolio holdings, resulting in higher transactions costs. In addition, as noted above, the models do not estimate the volatility (i.e., risk) of the portfolios well. As a result, DTSMs are not widely used in fixed-income portfolio management.

The second application where DTSMs may be useful is in the pricing and hedging of derivative securities. DTSMs price derivative securities by no-arbitrage arguments where the price of the derivative is equal to that of a basket of bonds. Thus, investors could, in theory, use these models to hedge their positions in derivatives. Unfortunately, the factors driving volatility in the bond markets do not appear to be the same as those driving volatility in the derivatives markets. As a result, more work is required to determine the precise causes of volatilities in the two markets.

The third application is in linking prices in the bond markets to macroeconomic variables. Using the bond market to extract more information about the state of the economy would be useful for central bankers and others. Collin-Dufresne noted that the models yield good information about the current state of the economy, but that what is of interest is its future state.

The final application is to use the models to learn more about the risk-return trade-off in the markets, which is the central question faced by any investor in these markets. Unfortunately, the price of risk yielded by DTSMs is often complex, highly volatile, and large. This makes identifying the trade-off between risk and expected return difficult.

Collin-Dufresne concluded by noting that academics, investors, and central bankers will have to resolve these issues in the future to make DTSMs more useful in practice.

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